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ERHYM-II: Model Description and User Guide for the BASIC Version

ABSTRACT

Wight, J. Ross. 1987. ERHYM-II: Model Description and User Guide for the BASIC Version. U.S. Department of Agriculture, Agricultural Research Service, ARS-59, 24 p.

ERHYM-II is a climate/water-balance rangeland model which simulates a complete, daily soil water balance. It can be used to predict peak standing crop herbage yields, based on the ratios of actual to potential transpiration and site yield potentials. It can utilize real-time climatic data to simulate ongoing processes or long-term weather records to simulate herbage yields under a range of climatic conditions. An upgraded version of ERHYM (Ekalaka Rangeland Hydrology and Yield Model), ERHYM-II includes routines for simulating soil temperatures, maximum-minimum air temperatures, solar radiation, and other minor modifications not present in ERHYM. The air-temperature and solar-radiation-generating routines enhance the model's application in areas where such climatic data are only limitedly available. The model program, which is written on a diskette for IBM and IBM compatible personal computers, can be obtained upon request from the author.

KEYWORDS: evapotranspiration, range herbage yield, rangeland model, transpiration, water balance

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ERHYM-II: MODEL DESCRIPTION AND USER GUIDE FOR THE BASIC VERSION

J. Ross Wight

INTRODUCTION

ERHYM-II is an upgraded version of ERHYM (Wight and Neff 1983). It includes additional routines for simulating soil temperature, maximum and minimum air temperatures, and solar radiation (R_s), plus a few minor modifications. The BASIC version of ERHYM-II is written for IBM and IBM compatible personal computers.

ERHYM-II is a climate/water-balance model which provides daily simulation of soil water evaporation, transpiration, runoff, and soil water routing for individual range sites. Herbage yield is computed annually at peak standing crop. The model can utilize real-time climatic data to simulate ongoing processes, or it can utilize long-term weather records to simulate runoff and herbage production under a range of climatic conditions and management practices. It can run either seasonally, with new soil water boundary conditions required at the beginning of each year's growing season, or continuously, utilizing a simple snowmelt-temperature relationship to account for snowmelt infiltration and runoff, and overwinter recharge. The model calculates infiltration and runoff from daily rainfall as described by Smith and Williams (1980). Evapotranspiration (ET), soil water routing, and herbage yield calculations are from Wight and Hanks (1981).

The model is process oriented and should work reasonably well when the parameters are adequately defined and weather records are available. Whenever possible, model output should be checked against field-measured values, particularly soil water content. Model performance can be improved by some adjustment of the soil and vegetation parameters.

The model description and user guide contains introductory and documentary material excerpted from the original ERHYM publication (Wight and Neff 1983), a brief description of the model, and a complete description of the parameter input file. Also included is a 5 1/4-inch, double-sided, double-density diskette which contains the ERHYM-II BASIC program file, ERHYM-II.BAS, and a 3-year climate file, CLIMATE.SEQ.

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Structure

The structure of the model is diagrammed in figure 1. The program begins by reading and printing the input parameters. The parameter data are stored in the data statement lines 9001 to 9020. These lines coincide with lines 1 through 20 in the parameter printout. The printout of the parameters is well labeled to enable a quick check for accuracy.

Following the initialization and title page printout, the program enters the MAIN section of the model. From MAIN, the climate component is called, and a climate record is read through to the end of the year and stored in an array. If air temperature and/or R_S is to be generated, the climate generating routine is called and a complete year's record of air temperature and R_S is generated and stored in an array. The climate generating routine can use either the computer's random number function or the model's random number routine.

After the current year's climate has been stored in an array, a relative growth curve is calculated and plotted.

A daily soil water balance is calculated by the DAYSSW component, which receives snowmelt and runoff calculations from MOISTURE and calculated soil temperatures from SOILT. The daily print routine is called from MAIN. Page headings are printed at the beginning and at 20-day intervals during each computer run. The summary print routine is called at the end of each year or each run. At the completion of a year's run, the program is

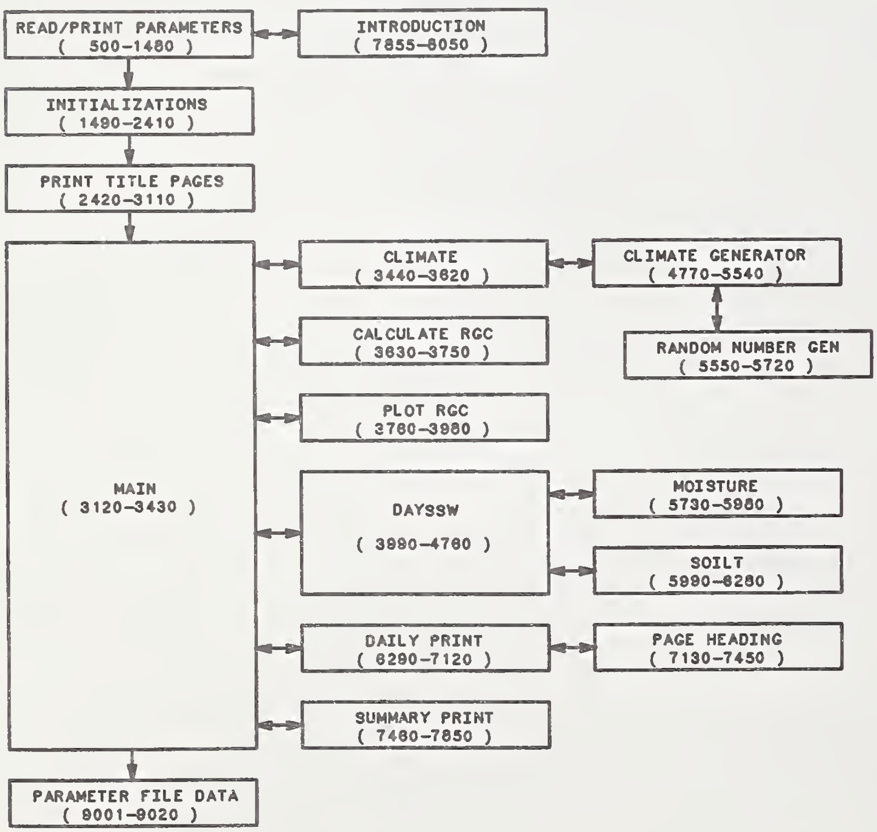

Figure 1.
Component structure of ERHYM-II.

either terminated or returns to the beginning of MAIN to make the next year's run.

Runoff

The runoff portion of this model as described here was taken directly from Smith and Williams (1980):

> The SCS curve number technique (USDA, Soil Conservation Service 1972) was selected for predicting runoff from daily rainfall because (1) it is a familiar procedure which has been used for many years in the United States; (2) it is computationally efficient; (3) the required inputs are generally available; and (4) it relates runoff to soil type, land use, and management practices. The use of readily available daily rainfall is a particularly important attribute of the curve number technique. For many locations, rainfall data with time increments of less than one day are not available. Also, daily rainfall data manipulation and runoff computation are more efficient than similar operations with shorter time increments.
>
> Traditionally, the SCS has used an antecedent rainfall index to estimate antecedent moisture as one of three conditions (I = dry, II = normal, and III = wet). The relation between rainfall and runoff for these three conditions is expressed as a curve number (CN). Each storm in a rainfall series is assigned one of the three curve numbers according to antecedent rainfall. In reality, CN varies continuously with soil moisture, and thus has many values instead of only three. Runoff prediction accuracy was increased by using a soil moisture accounting procedure to estimate the curve number for each storm (Williams and LaSeur 1976). Although the soil moisture accounting model was found to be superior to the antecedent rainfall method, it did not contain a percolation component or a physically based water balance. Also, the model required calibration with measured runoff data.
>
> Here the curve number technique was linked with evapotranspiration and percolation models to form a model capable of maintaining a continuous water balance. Calibration is not necessary, because the new model is more physically based.
>
> Besides predicting daily runoff volumes, an equation was also developed for predicting peak runoff rates. Tests with data from watersheds in Texas, Nebraska, Georgia, Ohio, Oklahoma, Arizona, New Mexico, West Virginia, Mississippi, Iowa, and Montana indicate that the model simulates runoff volumes and peak rates realistically.
>
> Runoff is predicted for daily rainfall using the SCS equation
>
> $$Q = \frac{(P - 0.2s)^2}{P + 0.8s} \quad \text{if } P > 0.2s \qquad [1]$$
>
> $$Q = 0 \quad \text{if } P < 0.2s$$
>
> where Q is the daily runoff; P is the daily rainfall; and s is a retention parameter, all having dimensions of length.
>
> The retention parameter s is related to soil water content with the equation
>
> $$s = s_{mx}\left(\frac{UL - SM}{UL}\right) \qquad [2]$$
>
> where SM is the soil water content in the root zone, UL is the upper limit of soil water storage in the root zone, and s_{mx} is the maximum value of s. The maximum value of s is estimated with the I moisture condition CN using the SCS (USDA, Soil Conservation Service 1972) equation
>
> $$s_{mx} = \frac{1,000}{CN_I} - 10 \qquad [3]$$
>
> where CN_I is the moisture condition I CN. An estimate of the moisture condition II CN can be obtained easily for any watershed using the SCS Hydrology Handbook (USDA, Soil Conservation Service 1972). [For operation of ERHYM, use the range site CN's reported by Hanson et al. (1981) in Table 1.]

For computing purposes, CN_I was related to CN_{II} with the polynomial

$$CN_I = 16.91 + 1.348(CN_{II}) - 0.01379 (CN_{II})^2 + 0.000177(CN_{II})^3. \quad [4]$$

If soil water is distributed uniformly in the soil profile, equation [2] should give a good estimate of the retention parameter, and thus the runoff; however if the soil water content is greater near the surface, equation [2] would tend to give low runoff predictions. Conversely, runoff would be overpredicted if the soil water content was greater in the lower root zone. To account for the soil water distribution, a weighting technique was developed. The root zone was divided into seven layers and weighting factors (decreasing with depth) were applied. [ERHYM uses the appropriate number of soil horizons up to a maximum of four layers.] The depth-weighted retention parameter is computed with the equation

$$s = sm_x \left[1.0 - \sum_{i=1}^{N} W_i \left(\frac{SM_i}{UL_i} \right) \right] \quad [5]$$

where W_i is the weighting factor, SM_i is the water content, and UL_i is the upper limit of water storage in storage i. The weighting factors decrease with depth according to the equation

$$W_I = 1.016 \left[e^{-4.16 \left(\frac{D_{i-1}}{RD} \right)} - e^{-4.16 \left(\frac{D_i}{RD} \right)} \right] \quad [6]$$

where D_i is the depth to the bottom of storage i and RD is the root zone depth. Equation [6] assures that

$$\sum_{i=1}^{N} W_I = 1.$$

The ET and percolation components of the model are described below. Since the model maintains a continuous water balance, mixed-land-use watersheds are subdivided to reflect differences in ET for various crops (range sites). Thus, runoff is predicted separately for each subarea and combined to obtain the total runoff for the watershed. Division by land use increases accuracy and gives a much better physical description of the water balance. [ERHYM considers only a single range site per run.]

Peak runoff rate is predicted with the equation

$$q_p = 200(DA)^{0.7}(CS)^{0.159} \cdot (Q)^{0.917(DA)^{0.166}} (LW)^{-0.187} \quad [7]$$

where q is the peak runoff rate in ft^3/s; DA is the drainage area in mi^2; CS is the mainstem channel slope in ft/mi; Q is the daily runoff volume in inches; and LW is the length-width ratio of the watershed. Data from 304 storms which occurred on 56 watersheds located in 14 states were used to develop equation [7]. Watershed areas ranged from 0.275 to 24 mi^2. Since these areas are larger than what is usually considered field-scale, the equation has variable exponents for DA and Q to accommodate areas down to one acre or less. These variable exponents simply prevent unreasonably high predictions for small areas.

Range site CN's in table 1, except for the thin claypan site, were developed and published in Wyoming (U.S. Department of Agriculture, Soil Conservation Service 1978). Hanson et al. (1981) compared several of the Wyoming CN's with CN's computed from actual watershed data and found excellent agreement. The CN list in table 1 is probably the best available for application to mixed prairie rangelands.

Smith and Williams' (1980) description of their runoff model continues:

> A simple snow accumulation and snowmelt equation is used by the model taken from Stewart and others (1975). For all those days when precipitation occurs when the temperature is less than 0° C, that precipitation is stored in the form of snow. When snow storage exists and the temperature, Temp, is above 0° C, daily snow-

Table 1.
Runoff curve numbers for range sites for the normal antecedent moisture condition, which is generally antecedent moisture condition II[1]

Range site	Range condition		
	Fair	High-fair and good	Excellent
Wetland	95	95	95
Very shallow	95	90	85
Saline subirrigated	90	90	85
Subirrigated	90	90	85
Shale	90	85	80
Dense clay	90	85	80
Alkali clay	90	85	80
Saline upland[2]	90	85	80
Igneous	90	80	75
Shallow clayey[2]	85	80	75
Shallow sandy	80	75	70
Shallow loamy[2]	80	75	70
Thin claypan[3]	80	75	70
Shallow igneous	80	75	70
Steep clayey	80	75	70
Clayey[2]	80	75	65
Gravelly loamy	80	75	65
Steep loamy	80	75	65
Overflow	80	70	60
Loamy overflow	80	70	60
Clayey overflow	80	70	60
Coarse upland	80	70	60
Limy upland	80	70	60
Shallow breaks	80	70	60
Stony	80	70	60
Steep stony	80	70	60
Lowland	80	70	60
Saline lowland	80	70	60
Loamy lowland	80	65	55
Loamy	80	65	55
Sandy lowland	75	60	50
Sandy[2]	75	60	50
Gravelly	70	55	45
Sands	70	55	40
Choppy sands	70	55	40

[1] For definitions of antecedent moisture conditions, see U.S. Department of Agriculture, Soil Conservation Service (1978).

[2] Range sites which were listed in U.S. Department of Agriculture, Soil Conservation Service (1978) and were verified by Hanson et al. (1981) using their watershed data.

[3] A South Dakota SCS range site designation.

Source: Curve numbers from Hanson et al. (1981).

melt (M) occurs, and input to the soil at the surface is calculated by

$$M = 0.18 \text{ Temp} \qquad [8]$$

unless M is greater than the amount of surface snow. Although this model is quite simplistic, it does help account for spring melt input, and would be difficult to improve without detailed daily temperature and radiation information.

Evapotranspiration and Soil Water Routing

The ET and soil water routing calculations are essentially the same as those made by Wight and Hanks (1981). Potential evapotranspiration (ET_p) is estimated with the equation Jensen and Haise (1963) used for calculating ET_p from a full cover of alfalfa with water nonlimiting for ET:

$$ET_p = (0.014\ F - 0.37)R_s/580 \qquad [9]$$

where F is the daily mean air temperature in degrees Fahrenheit and R_s is the solar radiation in langleys. R_s and F are obtained from weather records or are stochastically generated within the model.

The ET_p from native rangeland (ET_{pr}) is calculated as

$$ET_{pr} = ET_p \cdot CROPCO \qquad [10]$$

where CROPCO is the range crop coefficient. CROPCO used in this model was developed with lysimeter data from a mixed prairie range site in eastern Montana:

$$CROPCO = ET\ (\text{lysimeter})/ET_p\ (\text{water nonlimiting}). \qquad [11]$$

Potential transpiration (T_p) is calculated using the equation

$$T_p = TRANCO \cdot RGC \cdot ET_{pr} \qquad [12]$$

where TRANCO is a site specific transpiration coefficient and RGC is a relative growth curve. TRANCO is related to foliar cover and standing live phytomass and represents the maximum portion of ET_{pr} which can be transpiration (T). For a loamy range site in eastern Montana which averaged about 900 lb of phytomass/acre during a 12-year study, TRANCO was determined to be 0.5. Using the same relationship between TRANCO and live standing phytomass as described by Ritchie and Burnett (1971) for cotton and grain sorghum, TRANCO can be estimated for various range sites on the basis of average herbage yield (measured at ground level) by the equation

$$TRANCO = 0.0213 + 0.0162\ [\text{average site yield (lb/acre)}]^{1/2}. \qquad [13]$$

An RGC is used to indicate seasonal changes in standing live phytomass (fig. 2). The RGC will vary from season to season and among climatic regions and range ecosystems. The RGC's in figure 2 are described by a modification of the generalized Poisson density function reported by Parton and Innis (1972)

$$RGC = \left(\frac{x-b}{a-b}\right)^c \ EXP \left[\frac{c}{d}\left(1.0 - \left(\frac{x-b}{a-b}\right)^d\right)\right] \qquad [14]$$

where

RGC = seasonal growth expressed as a decimal fraction of 1.0,
a = Julian day peak standing crop occurs (PSCDAY),
b = Julian day growth curve starts (STRRGC),
c = a shape parameter for left side of curve (CSHAPE),
d = a shape parameter for right side of curve (DSHAPE).

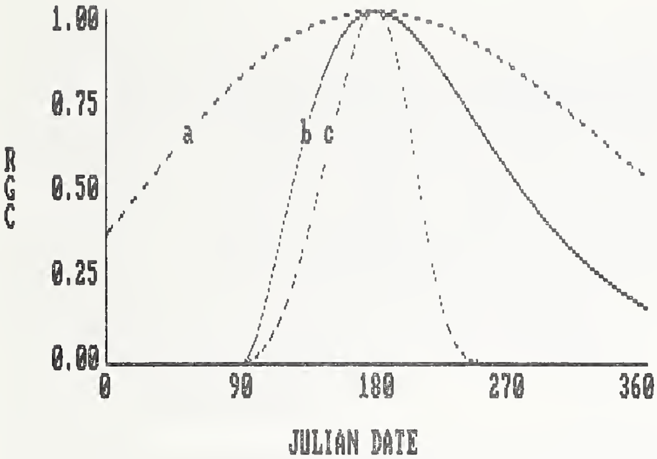

Figure 2.
Examples of the relative growth curves (RGC) which can be described by equation 14. The Julian day for peak standing crop (PSCDAY), start of the RGC (STRRGC), left side shape parameter (CSHAPE), and right side shape parameter (DSHAPE), respectively, are 182, -120, 2, and 2 for curve a; 182, 91, 2, and 1 for curve b; and 182, 191, 2, and 5 for curve c.

Equation 14 provides considerable flexibility in describing seasonal growth for a wide range of climatic conditions. Examples of the flexibility are presented in figure 2.

The STRRGC parameter is used to control the shape of the RGC and does not need to coincide with the actual beginning of the growing season. STRRGC can be adjusted along the Julian day time scale to develop a RGC which best represents the seasonal, aggregate growth of all the vegetation on the study site. The parameter RGCMIN provides a minimum RGC value for the entire year. When the equation-calculated value of RGC becomes less than RGCMIN, RGC is made equal to RGCMIN (fig. 3). This modification provides daily RGC values which can represent sites such as a sagebrush community, where the sagebrush component is relatively constant and maintains an actively transpiring leaf area throughout the entire year. The calculated RGC values are used to represent the growth dynamics during the growing season.

Actual soil water evaporation (E) is a function of both potential soil water evaporation (E_p) and time since the soil surface received a significant amount of precipitation. E is calculated by the equation

$$E = E_p / t^{1/2} \quad [15]$$

where t is the time in days since the occurrence of a precipitation event that was greater than 1.5 E_p, and where

$$E_p = ET_{pr} - T_p. \quad [16]$$

Soil water evaporates only from soil that is both wetter than air dry and present in the top 12 inches of the soil profile. In air-dry soils, the water content is depleted beyond the lower limits of availability to plants (permanent wilting point).

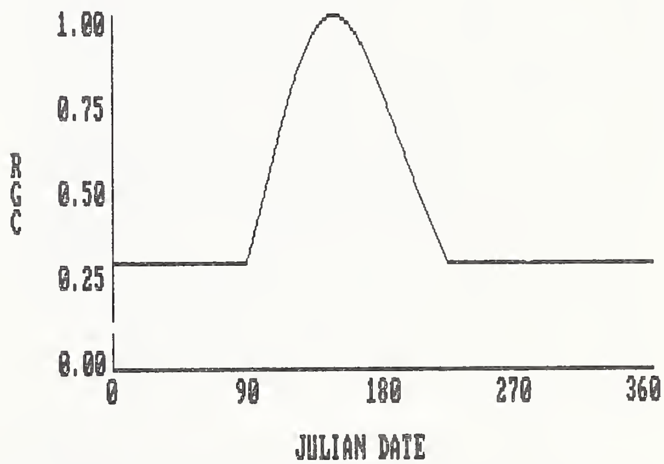

Figure 3.
An example of an RGC, using an RGCMIN of 0.3

Actual transpiration (T) is calculated by the equation

$$T = \sum_{i=1}^{n} T_p \, (SWS_i/AW_i \cdot ROOTF_i \cdot TEMFAC_i) \qquad [17]$$

where SWS_i is the available soil water in soil layer i; AW_i is the available soil water storage capacity for soil layer i; $ROOTF_i$ is a root density index for soil layer i; and $TEMFAC_i$ is a soil temperature factor calculated for each soil layer i using equation 18, which was developed from root-activity/temperature relationships presented by de Jong (1974). SOTP is the soil temperature value output by the soil temperature submodel for each soil layer:

$$TEMFAC = 0.0408 \;\; EXP\,(0.19\;SOTP); \quad TEMFAC \leq 1.0. \qquad [18]$$

In ERHYM-II, ROOTF is an input parameter which indicates relative root density in each soil layer, and it provides a means of restricting water uptake from the subsurface soil layers where root distribution is limited. ROOTF is the percent root density, expressed as a decimal fraction, relative to the root density in the surface soil layer, which is always 1.0. The subsurface layers can be 1.0 or less, depending on their root density relative to that of the surface layer. Water uptake from each soil layer is directly proportional to the value of ROOTF.

ROCKF is a factor used to account for the effect of the rock content on the conversion of gravimetric soil water values to volumetric values. The permanent wilting, field capacity, and initial soil water content data for each soil profile layer are expressed gravimetrically in the input parameter file. Often these values are determined from soil samples without correction for their rock contents. Thus in a soil profile containing a large proportion of rock, the conversion by the model of gravimetric water content values to volumetric water content values using the soil bulk density would greatly exaggerate the volumetric soil water content. The ROCKF correction is calculated as follows:

$$\text{Volumetric SWC} = (\text{gravimetric SWC}) \cdot (\text{bulk density}) \cdot (1.0 - ROCKF). \qquad [19]$$

ROCKF for any layer is its rock content that was not accounted for when the layer was analyzed gravimetrically for soil water content. It is expressed as a decimal fraction. For soil water measured volumetrically, ROCKF values of zero would be appropriate.

As the model operates, water is added to the soil by rain or other form of precipitation and removed by E, T, and drainage. The soil profile is divided into soil horizons, and water is added to or subtracted from one soil horizon or layer at a time. If, following a rain, the water content of the surface layer exceeds field capacity, water is added to the next layer and so on until all precipitation minus runoff is accounted for or until all soil layers are filled. Excess soil water is counted as drainage.

Soil water extraction also proceeds one layer at a time, beginning at the surface layer. If the surface soil layer cannot, under the imposed constraints, supply enough water to meet daily T_p, the model then extracts water from the second layer, and so on, until T_p has been satisfied or until all layers have been sampled. If T_p cannot be satisfied from soil layer i, then the full T_p demand is applied to soil layer i+1, but extraction cannot exceed the difference between T_p and T from the preceding soil layers.

Herbage Yields

Annual herbage yield (Y) at peak standing crop can be calculated from a climate index (T/T_p) with the equation

$$Y = (T/T_p)\ Y_p \qquad [20]$$

where Y_p is the site yield potential (site yield with water nonlimiting) or with the equation

$$Y = a + b\ (T/T_p) \qquad [21]$$

where the parameters a and b are calculated from a linear regression of field-measured yields on model-calculated climate indices.

The model-calculated climate index is a good indicator of the growing season climate as it relates to plant growth and enables comparisons of range treatments or vegetation inventories among years or range sites by accounting for a large portion of climate induced variation in plant response.

In the current version of ERHYM-II, two climate indices are calculated: the "old" and the "new." The old index is simply the ratio of cumulative T and T_p. The new yield index is calculated as the ratio of the area under the plotted, seasonal, cumulative T and T_p curves. The new index appears to correlate a little better to peak standing crop yields than the old index. When the model is operated for more than one year, the T and T_p values used in calculating the old yield index are cumulated from the first day of model run (STRDAY) to day of peak standing crop (PSCDAY) during the first year of simulation and from January 1 to PSCDAY during the subsequent years. In the colder northern climates, the values of T and T_p during the period between January 1 and STRDAY are low and have only a small effect on the seasonal T/T_p ratio. Also, the printout of total of T and T_p contains accurate cumulative values for the year, beginning STRDAY or January 1. Calculation of the new yield index is based on the T and T_p for the period each year between the start of the growing season (STRGRO) and PSCDAY.

Herbage Yield Forecasting

The herbage calculations made by the model can be used in a forecasting procedure, developed by Wight et al. (1984), which utilizes long-term weather records. A population of site specific annual climate indices is generated using the current year's (forecast year) beginning soil water content and daily precipitation, solar radiation, and temperature data from past weather records for the remainder of the growing season. Each year of historical data generates a climate index value. The generated populations of climate indices are usually normally distributed, and population means and standard deviations can be calculated and used to make probability forecasts.

Forecasts can be periodically updated throughout the growing season by utilizing the current year's daily precipitation and mean temperature data up to the date of forecast and historical data for the remainder of the growing season. A similar procedure could be used to forecast runoff.

Soil Temperature Submodel

ERHYM-II contains a soil temperature submodel taken from the EPIC model (Williams et al. 1982). The submodel is driven by mean monthly air temperature and soil water content. It outputs soil temperature for any specified soil depth on a daily basis. The submodel-calculated daily soil temperatures for the mean depth of each soil layer are used to control water uptake from each soil layer, as indicated in equation 18.

Stochastic Generation of Climatic Variables

The routines for generating R_s and maximum and minimum air temperatures in WGEN (Richardson and Wright 1984) have been added to ERHYM-II. These routines provide daily R_s and air temperature data as an option when such data are not available from local weather records. Model generated R_s is conditioned by actual daily precipitation values, thus reflecting daily variations in R_s. Generated R_s records are adequately similar to actual records so as to provide reliable results.

Generated air temperatures should be used with caution. The parameters for the climate generation routine (figs. 4-6) are based on climatic data from 31 weather stations throughout the United States (table 2) and do not reflect the local elevational effects on air temperature. It would be appropriate to compare the generated air temperatures with local climate records before using them in the model. Table 3 shows the effects of using generated temperature and R_s on some of the model outputs. Again, a word of caution: Data in table 3 represent only one, relatively short simulation period.

Inputs for generating R and air temperature are described in the parameter section, and parameter values are obtained in figures 4 through 6. The BASIC program contains a random number generator which can be used in place of the computer's random number function. It is activated by deleting program line 5210.

When the air temperatures, either from weather records or from the climate generator, represent a site or location that is at an elevation different from that to which the model is being applied, average daily temperature (AVTEMP) is adjusted by the equation

$$AVTEMP = AVTEMP - (DEL \cdot 0.00356) \quad [22]$$

where DEL is the difference (negative or positive) in elevation between site of model application and location of the weather station from which the air temperature data were obtained or the location for which they were generated (see table 2).

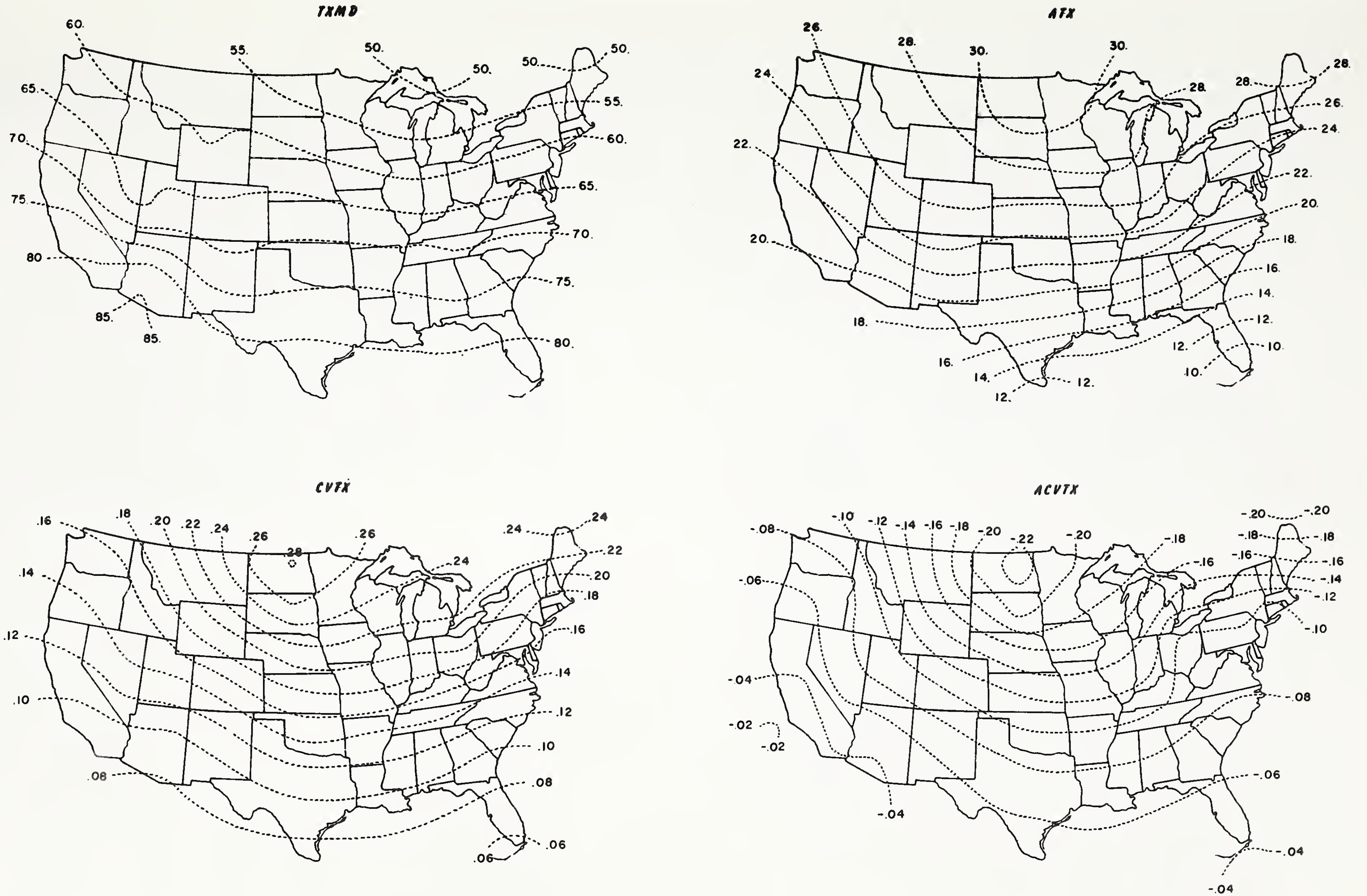

Figure 4.
Distributions of TXMD, ATX, CVTX, and ACVTX, contiguous United States.

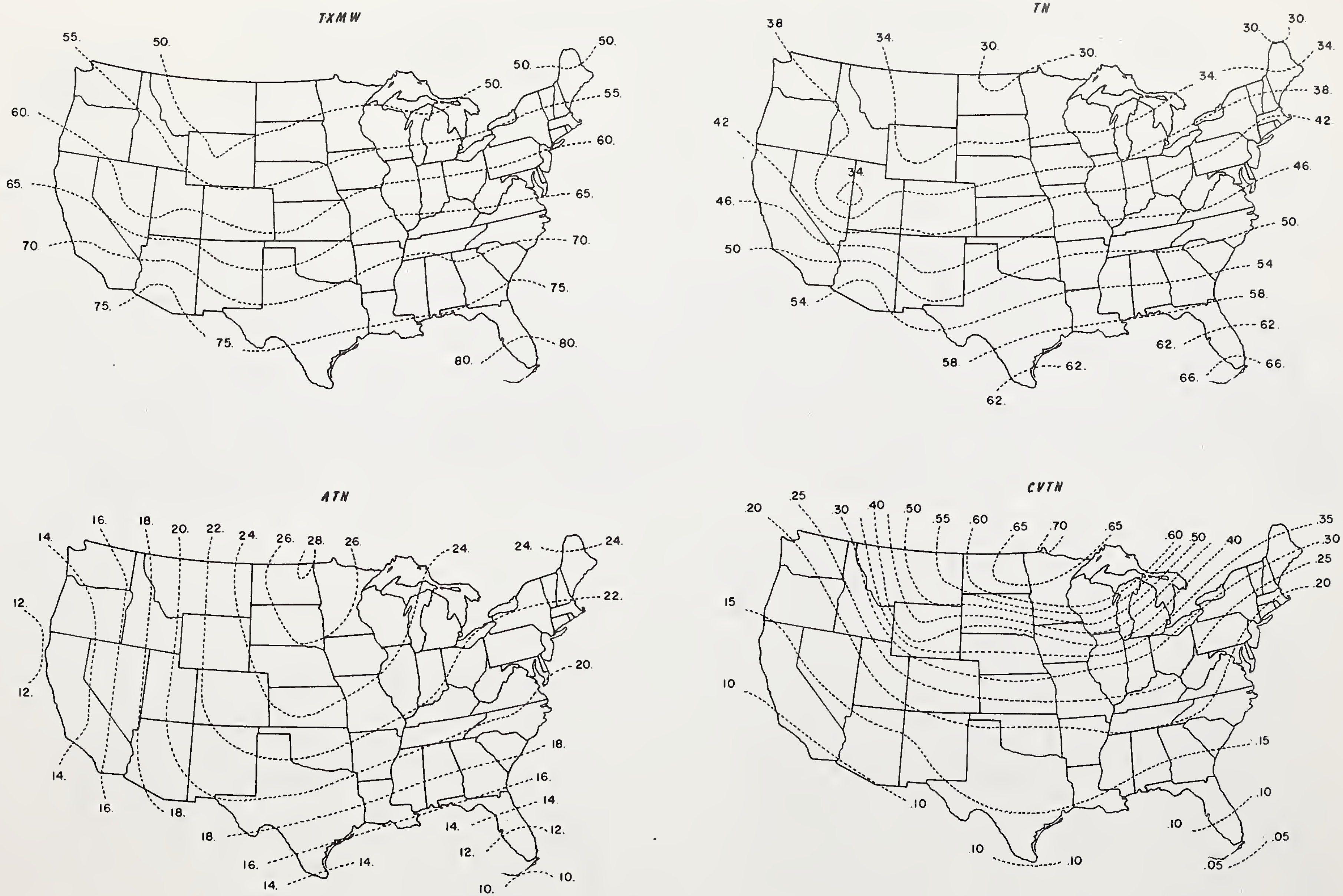

Figure 5.
Distributions of TXMW, TN, ATN, and CVTN, contiguous United States.

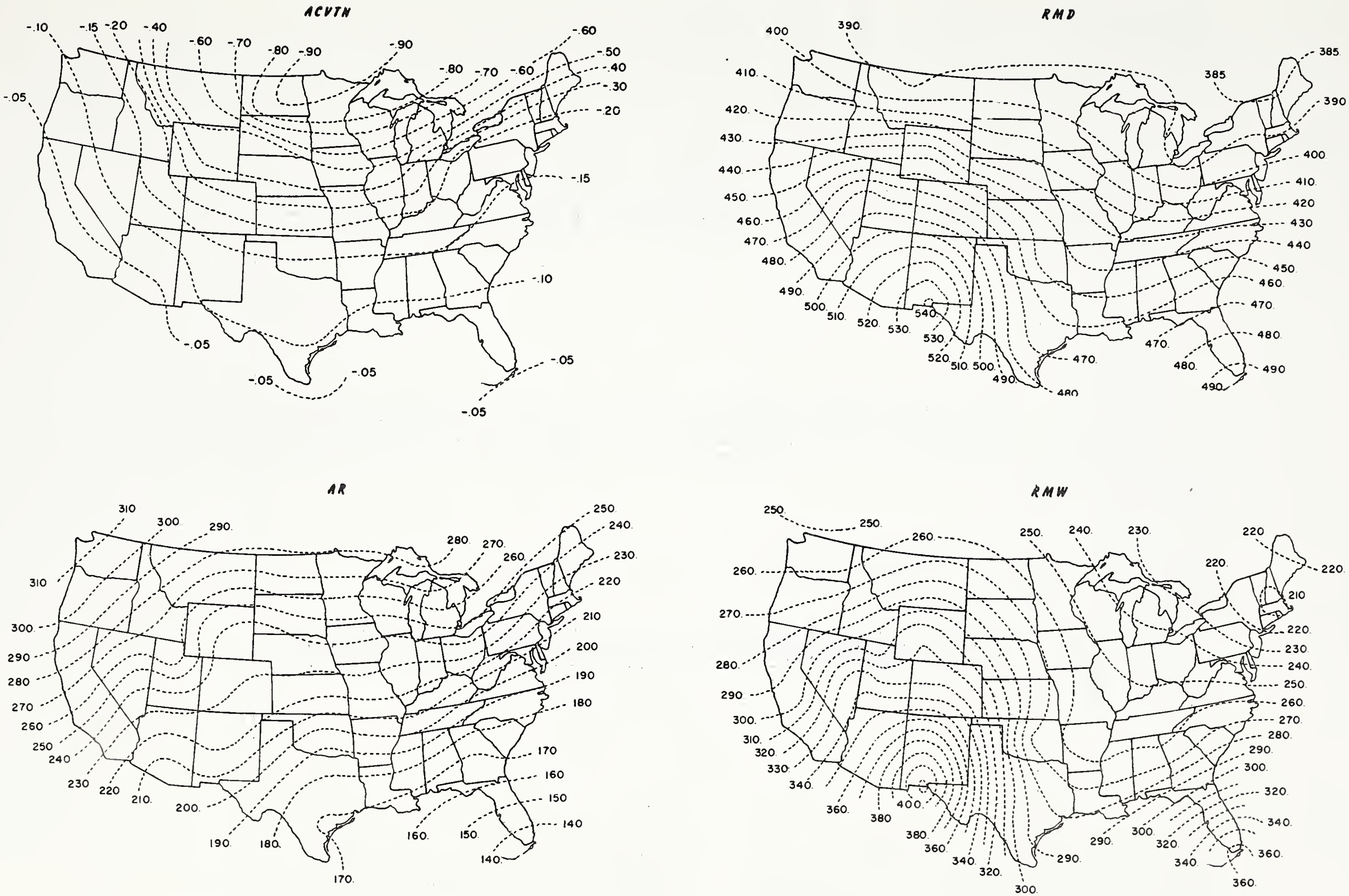

Figure 6.
Distributions of ACTVN, RMD, AR, and RMW, contiguous United States.

Table 2.
Weather station locations and elevations (from Richardson 1982)

Station	Latitude (°N)	Longitude (°W)	Elevation (m)
Albuquerque, NM	35.0	106.6	1618
Atlanta, GA	33.6	84.4	308
Bismarck, ND	46.8	100.7	502
Boise, ID	43.6	116.2	865
Boston, MA	42.4	71.0	5
Brownsville, TX	25.9	97.4	6
Caribou, ME	46.9	68.0	190
Charleston, SC	32.9	79.9	12
Cleveland, OH	41.4	81.7	237
Columbia, MO	38.8	92.2	237
Dodge City, KS	37.8	100.0	787
El Paso, TX	31.8	106.4	1194
Ely, NV	39.3	114.8	1905
Fresno, CA	36.8	119.7	100
Great Falls, MT	47.5	111.3	1116
Grand Junction, CO	39.0	108.5	1478
Greensboro, NC	36.0	79.9	273
Indianapolis, IN	39.7	86.1	241
Lander, WY	42.8	108.7	1696
Little Rock, AR	34.7	92.2	78
Madison, WI	43.1	89.3	261
Medford, OR	42.4	122.9	400
Miami, FL	25.8	80.3	2
Nashville, TN	36.1	86.7	177
Oklahoma City, OK	35.4	97.6	391
Phoenix, AZ	33.4	112.0	340
Rapid City, SD	44.1	103.3	1027
Salt Lake City, UT	40.8	112.0	1286
San Antonio, TX	29.5	98.5	240
Sault Ste. Marie, MI	46.5	84.4	220
Spokane, WA	47.6	117.5	716

Table 3.
Comparison of model-predicted[1] yield indices (YI), potential evapotranspiration (ET_p), actual evapotranspiration (ET), and actual transpiration (T) using real and generated temperature (Temp) and solar radiation (R_s) data

	YI	ET_p[2]	ET[2]	T[2]
Real Temp - real R_s	0.83	6.33	3.34	1.58
Real Temp - generated R_s	0.83	6.41	3.18	1.59
Generated Temp - real R_s	0.85	6.78	3.77	1.95
Generated Temp - generated R_s	0.87	6.41	3.58	1.62

[1] Model simulation period was from Julian day 90-160.

[2] Units are inches of water.

Input parameters for this model are readily obtainable from soil surveys, field observations, and the included tables and figures. A sample parameter file is included as part of the BASIC program and begins with data statement 9001. The climatic file is a separate sequential file and is called in line 3470 of the BASIC program. The file name must match the name called for in line 3470. Also, the input statements (lines 3490 and 3570) must match the format of the climate record in terms of the number and order of variables being read in each line. Variables in the climatic file which are not required by the model can be read using dummy variables such as DUM1, DUM2, and so forth, in program lines 3490 and 3570. The climatic file must include, as a minimum, the Julian day (1-366), year (two digits), and daily precipitation (inches or centimeters) for each day of the year the model is to be run (see the CLIMATE.SEQ file on the ERHYM-II diskette). By changing the INPUT statements to READ in lines 3490 and 3570, the climatic file can be entered as part of the BASIC program using Data Statement numbers beginning at 9021.

Soil parameters can be obtained from one or more of the following sources: Soil surveys, field measurements, and the soil-texture-based estimates in Table 4.

Table 4.
Field capacity, permanent wilting, bulk density, and air-dry values as related to soil texture

Texture	Computer code	Field capacity[1] Volumetric (g/cm^3)	Field capacity[1] Gravimetric (g/g)	Permanent wilting[1] Volumetric (g/cm^3)	Permanent wilting[1] Gravimetric (g/g)	Bulk density (g/cm^3)	Air-dry[2] (inches)
Sand	020	0.091	0.061	0.033	0.022	1.49	0.34
Loamy sand	060	.125	.084	.055	.037	1.49	.40
Sandy loam	100	.207	.143	.095	.066	1.45	.48
Loam	130	.270	.190	.117	.082	1.42	.52
Silt loam	140	.330	.250	.133	.101	1.32	.56
Sandy clay loam	160	.255	.159	.148	.092	1.60	.60
Clay loam	170	.318	.224	.197	.139	1.42	.80
Silty clay loam	180	.366	.261	.208	.149	1.40	.83
Sandy clay	190	.337	.223	.239	.158	1.51	.92
Silty clay	200	.387	.280	.250	.181	1.38	1.00
Clay	210	.396	.285	.272	.196	1.39	1.00

1 From Rawls et al. (1982).

2 The amount of water in the top 12 inches of soil profile held at tensions greater than permanent wilting which can be removed by evaporation.

Source: Wight and Neff (1983).

Table 5 is an example of the parameter file and indicates the order of parameter inputs in data statements beginning with line 9001. Table 6 is an example of the model output against which the parameter file can be checked. The parameter file is as follows:

Line 1

TITLE	One line of alphanumeric characters to be printed at the beginning of the output.

Line 2

PRTOPT	
1	Output option that emphasizes hydrology (table 7).
2	Output option that emphasizes ET (table 7).
DAYOPT	
1	Daily printout.
2	Yearly summary printout only, with a graph of the daily T/T_p values.
LOPT	
1	Inputs and outputs are in centimeters.
2	Inputs and outputs are in inches.
3	Precipitation input is in inches, and other inputs and outputs are in centimeters.

Line 3

STARTY	The last two digits of the first year of this run, for example, 72.
ENDY	The last two digits of the last year of this run, for example, 79.
STRDAY	Julian day the model starts, for example, 74.
ENDDAY	Julian day the model stops, for example, 180.

Soil Parameters

Line 4

SLARES	Number of a specific type of soil layer, for example, soil horizons with active roots present. Maximum of four.
AIRDRY	(One value in the same units as THK.) The amount of soil water (inches or centimeters) below permanent wilting which can be evaporated, for example, 0.7 (see table 4).
FURCAP	Surface water storage capacity, for example, contour furrows, in linear units (inches or centimeters), for example, 1.4. Units should be the same as for THK (see line 5).

Line 5

THK	(One value per soil layer.) Thickness of each soil layer. If LOPT (line 2) equals 1 or 3, then these values are assumed to be in centimeters. If LOPT equals 2, then these values are assumed to be in inches. If surface soil layer exceeds 12 inches (30.5 cm), it should be divided and entered as two equal soil layers.

Table 5.
An example of the parameter file input

```
9001 DATA TEST RUN
9002 DATA 1,1,2
9003 DATA 76,76,81,200
9004 DATA 4,.56,0
9005 DATA 9,9,12,12
9006 DATA 1.2,1.28,1.43,1.21
9007 DATA .03,.07,.08,.12
9008 DATA .27,.28,.22,.23
9009 DATA .31,.29,.25,.35
9010 DATA .17,.13,.17,.23
9011 DATA .8,.44,90,200
9012 DATA 1.0,.8,.3,.1
9013 DATA -20,150,15,1,.3
9014 DATA 10,.12,2,65,.2
9015 DATA 1,1,43.7,0,.70
9016 DATA 9,111,561,1001
9017 DATA 62.5,26,.155,-.085,56.5,37.5
9018 DATA 17,.225,-.145,430,285,288
9019 DATA 27.5,32.8,34.7,40.1,49.1,58.2
9020 DATA 67.8,67.2,57.3,46.7,35.1,28.8
```

Line 6

BDENST (One value per soil layer.) The bulk density (grams per cubic centimeter) for each soil layer, for example 1.3. (Can be estimated from table 4.)

Line 7

ROCKF (One value per soil layer.) Rock content not accounted for in gravimetric soil water analysis of the soil layer and expressed as a decimal fraction (0.0 to 1.0) on a volumetric basis.

Line 8

INITSM (One value per soil layer.) The initial soil water content (percent by weight expressed as a decimal fraction) for each soil layer, for example, 0.27.

Line 9

MHC (One value per soil layer.) Soil water content (percent by weight expressed as a decimal fraction) at field capacity, for example, 0.35. (Percent by volume/bulk density = percent by weight.) (Can be estimated from table 4.)

Line 10

UNASM (One value per soil layer.) Soil water content (percent by weight expressed as a decimal fraction) at permanent wilting for each soil, for example, 0.15. (Can be estimated from table 4.)

<u>Vegetation Parameters</u>

Line 11

CROPCO Crop coefficient, for example, 0.85.

TRANCO Transpiration coefficient. Estimated from equation 13.

STRGRO Julian day the model begins to accumulate T and T_p for calculation of the new yield index, for example 90 (used only with the new yield index.)

ENDGRO Julian day growing season ends, for example 200 (used only for plotting T/T_p when DAYOPT = 2).

Line 12

ROOTF (One value per soil layer.) The relative root density expressed as a decimal fraction (0.0 to 1.0) relative to the surface soil layer, which is always 1.0.

Line 13

STRRGC The value along the Julian day scale used to obtain the desired RGC. It can be a negative number, for example, -30.

PSCDAY Julian day of peak standing crop, for example, 180.

CSHAPE A shape parameter for left side of RGC, for example, 2.0.

DSHAPE A shape parameter for right side of RGC, for example, 2.0.

RGCMIN The minimum value that RGC can have during the entire year (must be between 0.0 and 1.0).

<u>Watershed/Climate Parameters</u>

Line 14

DACRE Area of field in acres, for example, 3.2.

CS Channel slope (ft/ft), for example, 0.022.

LW Watershed-length-to-width ratio calculated by squaring length and dividing by watershed area, for example, 2.0.

CN2 Condition II SCS curve number, for example, 80.0 (can never be less than 30). (See table 1.)

SIA Initial abstraction coefficient for SCS curve number, usually 0.20 (always input in inches).

Line 15

TEMOPT

0 Daily maximum and minimum air temperatures are generated in WGEN subroutine.

1 Daily maximum and minimum air temperatures are read from climate input file.

SOLOPT

0 Solar radiation values are generated in WGEN subroutine.

1 Actual solar radiation values read from climate input file.

XLAT The site latitude in degrees.

DEL The difference in elevation (in feet) between site of model application and location of weather station from which climatic records were obtained for climate file or were used in climate generator.

STWF A temperature weighting factor. It must have a value between 0.0 and 1.0 --usually about 0.70.

Line 16 K(1), K(2), K(3), K(4)

Seed numbers to initiate the random-number-generator routine. They must be odd integers with values greater than 100.

Line 17 (Terms relate to figs. 4 and 5.)

TXMD The mean of t_{max} (dry), °F.

ATX Amplitude of t_{max} (wet or dry), °F.

CVTX Mean coefficient of variation of t_{max} (wet or dry).

ACVTX Amplitude of coefficient of variation of t_{max} (wet or dry).

TXMW Mean of t_{max} (wet or dry), °F.

TN Mean of t_{min} (wet or dry), °F.

Line 18 (Terms relate to figs. 5 and 6.)

ATN Amplitude of t_{min} (wet or dry), °F.

CVTN Mean of coefficient of variation of t_{min} (wet or dry).

ACVTN Amplitude of coefficient of variation of t_{min} (wet or dry).

RMD Mean of solar radiation (dry), ly.

AR Amplitude of solar radiation (wet or dry), ly.

RMW Mean of solar radiation (wet), ly.

Line 19

TAO(1) TAO(2) TAO(3) TAO(4) TAO(5) TAO(6) Mean monthly air temperatures (°F) at the site of model application for January through June.

Line 20

TAO(7) TAO(8) TAO(9) TAO(10) TAO(11) TAO(12) Mean monthly temperatures (°F) at the site of model application for July through December.

Table 6.
An example of the model output of the parameter file

```
CHECK PARAMETER FILE

LINE - 1                 ******* TEST RUN ********

                           1           1          2
LINE - 2                 PRTOPT      DAYOPT     LOPT

                          76          76         81         200
LINE - 3                 STARTY     ENDY        STRDAY     ENDDAY

                          4.00        0.56       0.00
LINE - 4                 SLARES      AIRDRY     FURCAP

                               SOIL LAYERS
                           1         2         3         4
LINE - 5      THK         9.00      9.00     12.00     12.00
LINE - 6      BDENST      1.20      1.28      1.43      1.21
LINE - 7      ROCKF       0.03      0.07      0.08      0.12
LINE - 8      INITSM      0.27      0.28      0.22      0.23
LINE - 9      MHC         0.31      0.29      0.25      0.35
LINE - 10      UNASM      0.17      0.13      0.17      0.23

PRESS ANY KEY TO CONTINUE
                    --------VEGETATION PARAMETERS--------

                     0.80        0.44        90.00      200.00
LINE - 11           CROPCO      TRANCO      STRGRO     ENDGRO

                     1.00        0.80        0.30        0.10
LINE - 12           ROOTF1      ROOTF2      ROOTF3     ROOTF4

                    -20.00     150.00      15.00       1.00        0.30
LINE - 13           STRRGC     PSCDAY      CSHAPE     DSHAPE      RGCMIN

PRESS ANY KEY TO CONTINUE
                    --------WATERSHED/CLIMATE PARAMETERS--------

                     10.00       0.12        2.00       65.00        0.20
LINE - 14           DACRES        CS          LW         CN2          SIA

                     1.00        1.00       43.70        0.00        0.70
LINE - 15           TEMOPT      SOLOPT      XLAT         DEL         STWF

                        9         111        561        1001
LINE - 16           KSEED1      KSEED2     KSEED3     KSEED4

                  62.500    26.000     0.155    -0.085    56.500    37.500
LINE - 17           TXMD       ATX      CVTX      ACVTX      TXMW       TN

                  17.000     0.225    -0.145   430.000   285.000   288.000
LINE - 18           AOTN      CVTN      ACVTN      RMD        AR        RMW

                   27.50     32.80     34.70     40.10     49.10     58.20
LINE - 19           JAN       FEB       MAR       APR       MAY       JUN

                   67.80     67.20     57.30     46.70     35.10     28.80
LINE - 20           JUL       AUG       SEP       OCT       NOV       DEC
PRESS ANY KEY TO CONTINUE
```

Table 7.
Examples of the 2 daily printout options

PRTOPT = 1

DAY	TEMP	PREC	ROFF	PEAK	SNOW	POTENTIAL EVAP	POTENTIAL TRAN	ACTUAL EVAP	ACTUAL TRAN	SOIL WATER 1	SOIL WATER 2	SOIL WATER 3+4
81	38	0.00	0.00	0.00	0.00	.04	.01	.04	.00	2.79	3.00	6.41
82	41	0.03	0.00	0.00	0.00	.02	.00	.02	.00	2.79	3.00	6.41
83	32	0.00	0.00	0.00	0.00	.01	.00	.01	.00	2.78	3.00	6.41
84	37	0.15	0.00	0.00	0.00	.01	.00	.01	.00	2.92	3.00	6.41
85	28	0.00	0.00	0.00	0.00	.01	.00	.00	.00	2.91	3.00	6.41
86	35	0.03	0.00	0.00	0.00	.02	.00	.02	.00	2.92	3.00	6.41
87	27	0.03S	0.00	0.00	0.03	.00	.00	.00	.00	2.92	3.00	6.41
88	28	0.15S	0.00	0.00	0.18	.00	.00	.00	.00	2.92	3.00	6.41
89	30	0.00	0.00	0.00	0.17	.01	.00	.01	.00	2.92	3.00	6.41
90	42	0.00	0.00	0.00	0.00	.06	.01	.03	.01	3.05	3.00	6.41
91	42	0.00	0.00	0.00	0.00	.04	.01	.02	.01	3.02	3.00	6.41
92	26	0.00	0.00	0.00	0.00	.00	.00	.00	.00	3.02	3.00	6.41
93	30	0.00	0.00	0.00	0.00	.01	.00	.00	.00	3.01	3.00	6.41
94	41	0.00	0.00	0.00	0.00	.05	.01	.02	.01	2.99	3.00	6.41
95	47	0.00	0.00	0.00	0.00	.07	.01	.03	.01	2.95	3.00	6.41
96	50	0.00	0.00	0.00	0.00	.05	.01	.02	.01	2.92	3.00	6.41
97	41	0.02	0.00	0.00	0.00	.03	.01	.02	.01	2.92	3.00	6.41
98	44	0.00	0.00	0.00	0.00	.06	.01	.02	.01	2.89	2.99	6.41

PRTOPT = 2

DAY	EO	PREC	POTN TRAN	ACTU EVAP	ACTUAL TRAN 1	ACTUAL TRAN 2	ACTUAL TRAN 3	ACTUAL TRAN 4	SOIL WATER 1	SOIL WATER 2	SOIL WATER 3	SOIL WATER 4	T/TP
81	0.05	0.00	0.01	0.04	0.00	0.00	0.00	0.00	2.79	3.00	3.47	2.94	0.84
82	0.04	0.03	0.00	0.02	0.00	0.00	0.00	0.00	2.79	3.00	3.47	2.94	0.83
83	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	2.78	3.00	3.47	2.94	0.80
84	0.02	0.15	0.00	0.01	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.89
85	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.91	3.00	3.47	2.94	0.86
86	0.03	0.03	0.00	0.02	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.86
87	0.00	0.03S	0.00	0.00	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.85
88	0.00	0.15S	0.00	0.00	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.84
89	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.83
90	0.08	0.00	0.01	0.03	0.01	0.00	0.00	0.00	3.05	3.00	3.47	2.94	0.92
91	0.06	0.00	0.01	0.02	0.01	0.00	0.00	0.00	3.02	3.00	3.47	2.94	0.90
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.02	3.00	3.47	2.94	0.89
93	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.01	3.00	3.47	2.94	0.89
94	0.08	0.00	0.01	0.02	0.01	0.00	0.00	0.00	2.99	3.00	3.47	2.94	0.87
95	0.11	0.00	0.01	0.03	0.01	0.00	0.00	0.00	2.95	3.00	3.47	2.94	0.86
96	0.08	0.00	0.01	0.02	0.01	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.85
97	0.04	0.02	0.01	0.02	0.00	0.00	0.00	0.00	2.92	3.00	3.47	2.94	0.85
98	0.10	0.00	0.01	0.02	0.01	0.00	0.00	0.00	2.89	2.99	3.47	2.94	0.84

The model output has been programmed for screen display. A hard copy of output can be obtained by activating the "Print Screen" key or by reprogramming the print statements to output to a printer.

Model output can be either on a daily or annual basis. With the annual summary option (DAYOPT = 2), the daily T/T_p ratio is plotted. Output options are also available that emphasize different components of the daily water balance calculations (table 7).

Precipitation (PREC), runoff (ROFF), snow depth (SNOW), evaporation (EVAP), and transpiration (TRAN), and soil water content (SOIL WATER) in layers 1 through 4 are in units of either inches or centimeters, depending on the value of LOPT. For PRTOPT = 1, mean daily air temperature (TEMP) is in degrees Fahrenheit and peakflow (PEAK) is in either cubic feet per second or cubic meters per second. For PRTOPT = 2, EO is the Jensen-Haise (1963) calculated potential ET; ACTUAL TRAN is the calculated transpiration water extracted from each soil layer; and T/T_p is the ratio of actual and potential transpiration for each day.

The program file, ERHYM-II.BAS, is written in Microsoft BASIC - BASIC VERSION 2, which requires MS-DOS VERSION 2.0 or later to execute. ERHYM-II.BAS contains a set of parameters in lines 9001-9020 for a demonstration run using climatic data from CLIMATE.SEQ. Most of the ERHYM-II program is written with only one statement or command per line. This structure simplifies program changes or modifications by model users.

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